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(1)

MECHANISM OF JOINTS.

BY

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EXTRACTED FROM THE TRANSACTIONS OF THE
INTERNATIONAL MEDICAL CONGRESS,
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THE MECHANISM OF JOINTS.

The[1] limb being subservient to both support and motion, it is reasonable to expect that in certain joints the former function should be observed, and in others the latter. When the apparatus for support is conspicuous, the joint may be said to be of static value. But when this purpose is subordinate to flexion (*i. e.* deviation from the axial line of the limb), the joint may be said to be of dynamic value.

The most striking distinctions between the static and dynamic articulations lie in the relations of the opposed surfaces. To explain this portion of my remarks a few words of a general character are necessary. I premise that the typical "ball and socket" joints consist of well-defined balls embraced by perfect sockets. No such joints are found outside of the vertebral column. The articulations between the bodies of the vertebræ, although spoken of as amphiarthroses, are in truth "balls and sockets." The central intervertebral mass is the "ball;" the opposed vertebral surfaces and the peripheral interlacing fibrous bands of the disk make up the "socket." I also premise that the simplest forms, or at least the first forms, of joints appear in the vertebral column, since this structure answers to the axial line of the body. The movable union between any pair of segments or bodies of this axis may be taken as typical of what is possible under more complex conditions elsewhere. If it is remembered that a rod or axis cannot be projected far without segmenting, the best basis is secured upon which to rest any consideration of arthrosis. Obviously *motion* between a pair of bony segments is the main fact to consider in every problem. The questions which I believe can be asked with reference to further development of this theme are, in what way is *support* secured through a series of such mobile joints, and how can the apparatuses of *motion* be varied?

The limb is a special structure appended to the body. It moves chiefly at the joint between its first and second bones. This joint, in both the anterior and posterior extremities, is a ball and socket, as usually described. But it evidently in each instance is a portion of a ball opposed to a partial socket; since only small portions relatively of the head of the humerus or femur can be brought in relation to the socket at one time. So generally throughout the limbs (although in less marked degree), it is found that segments of spheroids play within concave surfaces. I propose to call all such surfaces modified balls and sockets (the type of which is exhibited only in the vertebral column), and proceed to define the two main varieties, named above, to wit: (1) Where the rela-

[1] [This paper is an abstract of a more elaborate study which the author reserves the right of publishing hereafter in a separate form.—Editor.]

tions between the two surfaces are such that the ball lies in its socket, and suggests *rest*. (2) Where the ball is suspended from the socket, and suggests *motion*. The occipito-atloid articulation is an example of the first, and the temporo-maxillary of the second variety.

The dynamic joints are apt to be crossed by powerful muscles, if indeed it may not be said of them that the muscles aid to a great degree in maintaining the efficacy of the articulations. Thus if the muscles about the shoulder-joint are divided, the humerus breaks contact with the scapula, and the joint is destroyed. This is also true of some other articulations, as the temporo-maxillary, in part. In some other instances of the same variety, the relation while not maintained by muscular action is strengthened by the presence of muscles crossing the joint, as at the ankle and wrist-joints.

As in all other studies in biological science, typical forms are united by intermediate ones. Some joints, as the knee and elbow, do not naturally fall within either static or dynamic kinds. The elbow-joint is especially difficult to study, it being varied from its type to a remarkable degree. The knee-joint, although exceedingly intricate, is resolvable in its several portions to static and dynamic functions, the structural modifications from typical points being pronounced. In the same way the first or swinging joints in the respective limbs, while of the same variety, since the ball is suspended from the socket in both, differ from each other in that the hip-joint is more fixed than the shoulder-joint. In a word the hip-joint is a dynamic joint, modified or specialized to do static work. In order that the work can be done effectively, stout bands cross its capsule, and the head of the femur is received within the acetabulum in such wise that the weight of the body is borne, not upon the centre of the head of the bone, but upon its upper surface.

If these general statements be remembered in studying the etiology of fracture and dislocation, more especially in examples of indirect violence, it will be recognized that a static joint will not be apt to be dislocated as long as the weight of the superincumbent mass presses directly within the socket. Thus a dislocation at the occipito-atloid articulation is rare, as is dislocation of the astragalus. But if the force be obliquely directed, causing the weight to be received violently against the side of the socket, then the joint may easily be luxated.

In the many positions assumed by the body, it often happens that an injury may be sustained from a reversal of the normal or typical relation. Thus while the extremities are described from the shoulder down, with the hands free (the main idea of the entire limb being *motion*), it becomes a different subject when studied with the limb suddenly assuming a *supporting* use—as for example when the body falls forward, and the hand strikes the ground while the limb is extended. Here the head of the humerus is driven up against its socket by the downward weight of the body, and the idea of swinging is lost. In a word, a dynamic joint is abruptly called upon to be a static one. A natural result is luxation of the shoulder, or, if the muscles about the joint be particularly rigid, fracture of the clavicle. In less degrees of violence, the force being expended nearer the hand, the wrist is either luxated or the radius broken. In medium degrees of violence, particularly seen in young subjects, the outer condyle of the humerus will break by the weight of the body being thrown through the convex radial head of the humerus downward upon the fixed concavity of the head of the radius, provided that the arm be forcibly extended. If the arm be partially flexed, the

weight of the body being transmitted to the forearm at an angle, the humerus will be apt to break transversely a little above the elbow-joint.

I do not speak here of the frequency of such fractures induced by indirect violence, but only of the way in which the articular surfaces as described would in my judgment behave under the circumstances detailed.

The lower limb, however, is always prepared for the conduction of lines of force so exceptional in the upper. The whole limb, while expressing motion, is also designed to sustain the weight of the body. Hence the greater strength of the joint surfaces, as well as the more prop-like appearance of the limb. In walking, the weight of the body is sustained for one moment at the astragalo-scaphoid joint in a nearly straight line, embracing, in the limb, the femur, tibia, and astragalus. The scaphoid bone and the inferior calcaneo-scaphoid ligament constitute a socket which receives and sustains this enormous weight. In falls from a height, which terminate by the foot striking, the weight not being received directly within the centre of the socket may be deflected, and luxation of the astragalus may occur. But from the rarity of this accident I infer that the mere exaggerations of the lines of force acting in its accustomed directions, are less injurious than the same kind of force acting upon the superior limb which is taken at a disadvantage.

The remainder of my remarks will be in application of the above data to the study of joints, including new observations of some special forms of articulation.

In the knee-joint, for example, I think that it can be shown, from the shapes of the articular surfaces, that the outer femoral condyle is the static or axial half, and the inner is the dynamic or swinging half. This study involves many details which would occupy too much time to elaborate.[1] Suffice it to say, however, that when a person stands erect, the femur rests upon the tibia as a ball in its socket, chiefly through its outer condyle. In flexion, this condyle is "switched off" (for the most part through the action of the popliteus muscle upon the outer semilunar cartilage), while the swinging of the inner condyle of the tibia upon the inner femoral condyle is initiated—not, it is true, by a ball suspended from its socket, as much as by a gliding of a shallow concave tibial surface upon a slightly convex femoral surface.

The term "switching off," as applied to the outer femoral condyle in passing from extension to flexion, needs explanation. The outer tibial condyle is observed to be convex toward the tibial spine. It is evident that, if any portion of the convex surface of the femoral condyle comes in contact with this convexity, no support is possible. This is what takes place when the knee is flexed. But when it is extended, the femoral condyle is placed firmly in a tibial concavity, the inner boundary of which is now formed by this eminence. As above stated, the outer semilunar cartilage is the factor producing the change. The outer tibial condyle is a true saddle surface, modified by the presence of the semilunar cartilage. The best example of a pure saddle surface is seen on the proximal surface of the trapezium. Here the convexity increases also toward the inner border. The first metacarpal bone of the thumb may be described as lodged upon this convexity in flexion of the thumb, and

[1] The details embrace the study of the cancelli of both femur and tibia, the shapes of the femoral, tibial, and patellar facets, the shapes and motions of the semilunar cartilages, as well as a refreshened account of the so-called crucial ligaments.

as relaxed or "switched off" in extension. It is evident that this lodgment and relaxation must be limited by appropriate ligaments. Inordinate or uncorrelated motions determine dislocation.

In the limbs of some lower animals, special adaptations in joints are recognized, which result in fixing or locking some of the facets. The immediate result of such locking is to conserve muscular power. Applications of this principle to some joints in the human frame may prove useful. Thus the knee-joint is nearly immobile at forced flexion or forced extension, but is freely movable at points between. It is probable that a careful study of other joint-surfaces will show similar peculiarities.

The facets upon the ends of bones are arranged in the order of the succession of the bones themselves in a given limb. The most evident arrangement is to have a facet upon the proximal and distal surfaces of each bone, in such wise as to allow the longitudinal axis to answer to the centre of each facet. These may be termed primary facets, since they are the most constant in any series of studies, and are least subject to change in special apparatuses. Assuming that the generalization of Goodsir is correct, that a process sent from the main shaft of a bone, as from the ribs of fishes and birds, may be termed a rayed process or actinopophysis, I will suggest that the same term may be given to the analogous process in a forked rib. If this be conceded, I think it not improbable that, in the event of the shaft of a bone and its actinopophysis becoming facet-bearing, such ray-borne articular surface should receive the name of actinic, or secondary surface. I believe that the inner femoral condyle is an instance of such a surface. I also believe that the surfaces upon the sides of certain bones, as those between tarsal and metatarsal bones, and between the tibia and fibula, or between the radius and ulna, are of subordinate value to the primary facets, since they appear to be caused by mutual compression of the bones themselves, and hence may be termed lateral or tertiary facets.

A joint may be said to be at rest when the least pressure exists between its opposed facets. The supine position will tend to rest static joints, since it diminishes the pressure of the weight. It will not, necessarily, so rest completely dynamic joints, since the muscles may be more or less active in the supine position. The lower jaw, for example, is not so rested. It is evident that to place in absolute rest a joint of this kind, its muscles must be kept from contracting. Any apparatus, therefore, to keep a joint at rest, must include all the muscles influencing the joint. When it is recalled that in the lower extremity the muscles are so disposed that the contraction of those arising from the hip effects changes in portions beyond the knee, and even down to the foot, it may be concluded that to make quiet any one, or part of one, of these surfaces, the entire limb should be kept quiet.[1]

It is at the same time true that, in a joint in which the articular surface on one side is larger than that on the other, those portions at any time not in use, may be said to be at rest. Thus, in the knee, some portions of the condyles are at rest in extension, while others are at rest in flexion. It follows from this that, in diseased action, products of pathogenesis will be absent from surfaces removed from pressure or friction.

[1] Rest is perhaps best secured at semi-flexion, *i. e.*, at the point at which extension ceases, and flexion has but just begun. All parts are then relaxed. This, while a theoretical point in some joints, has fixed value at the knee.

Now pressure long continued will destroy tissue, while friction will induce hypernutrition. It can be seen when a diseased joint is examined, with this fact in mind, at which points the pressure, and at which the friction has been. Thus in a knee-joint long the seat of chronic rheumatic arthritis, the outer condyle of the tibia will be found reduced in size, while the inner will be exaggerated. Also knee-joints flexed in diseased conditions will have points of pain localized at the inner side, while knee-joints extended in similar conditions will have like points developed upon the outer side.

If the outer condyle is axial, it will so remain, no matter what portion of the axis is reserved for articulation. So that in motion, after excision of the knee-joint, the line of axial support is preserved, and a good limb for *standing* is secured. But in consequence of the special apparatus for *flexion* having been removed, the limb below the knee is a mere wabbling appendage during attempts at bending.